Journal of the Society for Cardiovascular Angiography & Interventions 4 (2025) 102501

JSCAI

The official journal of the Society for
Cardiovascular Angiography & Interventions

JSCAI Case Report

New Covered Stent Design for Correcting Sinus Venosus Defects and a Novel Deployment Technique: A Case Series

Kothandam Sivakumar, MD, DM [*], Pramod Sagar, MD, DM,
Thejaswi Puthiyedath, MD, DrNB

Department of Pediatric Cardiology, Institute of Cardio Vascular Diseases, Madras Medical Mission, Chennai, Tamil Nadu, India

ABSTRACT

Transcatheter correction of sinus venosus defects use balloon-expandable covered stents across the cavoatrial junction to redirect the anomalous right upper pulmonary vein to the left atrium. When the superior vena caval anchor zone is very short, the stent slips caudally, causing residual flows from the right upper pulmonary vein through the cranial end of the stent or embolizes to the right atrium. We report use of a new hybrid stent with an uncovered cranial part deployed by a novel 2-wire strategy that enabled a safe procedure in patients with sinus venosus defects and a short superior vena caval anchor zone.

Transcatheter correction of sinus venosus defects (SVDs) using balloon-expandable covered stents is an emerging alternative to surgery.[1–3] A long covered stent anchored from the superior vena cava (SVC) to the right atrium (RA) roofs the SVD and redirects the anomalous right upper pulmonary vein (RUPV) toward the left atrium (LA). Short anchor zone when additional high pulmonary vein enters the SVC predisposes to stent migration. Left brachiocephalic vein may get jailed by a covered stent in short SVC.[4] An 80.0-mm long Zephyr covered stent (Sahajanand Laser Technology) was modified in the factory to leave the cranial 16.0 mm without expanded polytetrafluoroethylene fabric lamination.[5] A novel 2-wire technique was planned for a precise position of this hybrid stent. A Lunderquist wire (Cook Medical) was placed into the right internal jugular vein, and an additional Amplatzer super stiff wire (Boston Scientific) was placed into either the additional high-draining PV to preserve its drainage into the SVC or in the left innominate vein in case of a short SVC length (Figure 1). This hybrid stent design and twin-wire deployment technique was evaluated in 3 cases of whom 2 had an additional high-draining vein and 1 had a very short SVC. Patients provided informed consent for the use of this hybrid stent through 2-wire technique as well as an anonymized reporting.

Case 1

Cardiac computed tomography (CT) in a 43-year-old woman with SVD and mild pulmonary hypertension showed single right SVC measuring 19.0 mm in diameter, anomalous RUPV drainage to the right wall of the SVC, and an additional vein from the upper lobe of the right lung entering the posterior wall of the SVC, 1.0 cm cranial to the main RUPV (Figure 2). Heart team considered surgical difficulties in redirecting this high-draining additional vein and opted for transcatheter closure with the hybrid stent deployed by the 2-wire technique.

Under transesophageal echocardiography, the RUPV was cannulated from a left femoral vein sheath placed after puncturing the oval fossa through the LA. Balloon interrogation of SVC-RA junction used a 24.0-mm × 85.0-mm BIB balloon (NuMED) through a long 24F right femoral sheath over a Lunderquist wire placed in the right jugular bulb. The additional high-draining vein was cannulated in parallel using a right coronary guide catheter from the same right femoral venous sheath on a separate Amplatz superstiff wire. RUPV angiogram during the balloon interrogation showed its redirection to the LA without any elevation of its pressures, while the additional vein injection confirmed its nonroutable nature (Figure 2). An 80.0-mm hybrid covered Zephyr stent was mounted on the same BIB balloon along with a parallel coronary guide catheter (Figure 1). The tip of the guide catheter was brought out of the junction of the uncovered and covered part of the stent. After crimping the stent over the balloon and guide catheter, the assembly was covered with a short protective sleeve. The balloon and the guide catheter lumen were advanced through the Lunderquist and Amplatz superstiff wires, respectively, to the cavoatrial junction. RUPV angiogram after covered-stent expansion confirmed its redirection to the LA without any significant residual leak. Angiogram from the additional vein confirmed its drainage into the SVC (Figure 2). After 1 month of dual antiplatelet therapy, follow-up transesophageal

Keywords: additional pulmonary vein; anchor zone; anomalous right upper pulmonary vein drainage; short superior vena cava; stent embolization; Zephyr covered stent.
* Corresponding author: drkumarsiva@hotmail.com (K. Sivakumar).

https://doi.org/10.1016/j.jscai.2024.102501
Received 15 September 2024; Received in revised form 16 October 2024; Accepted 1 December 2024

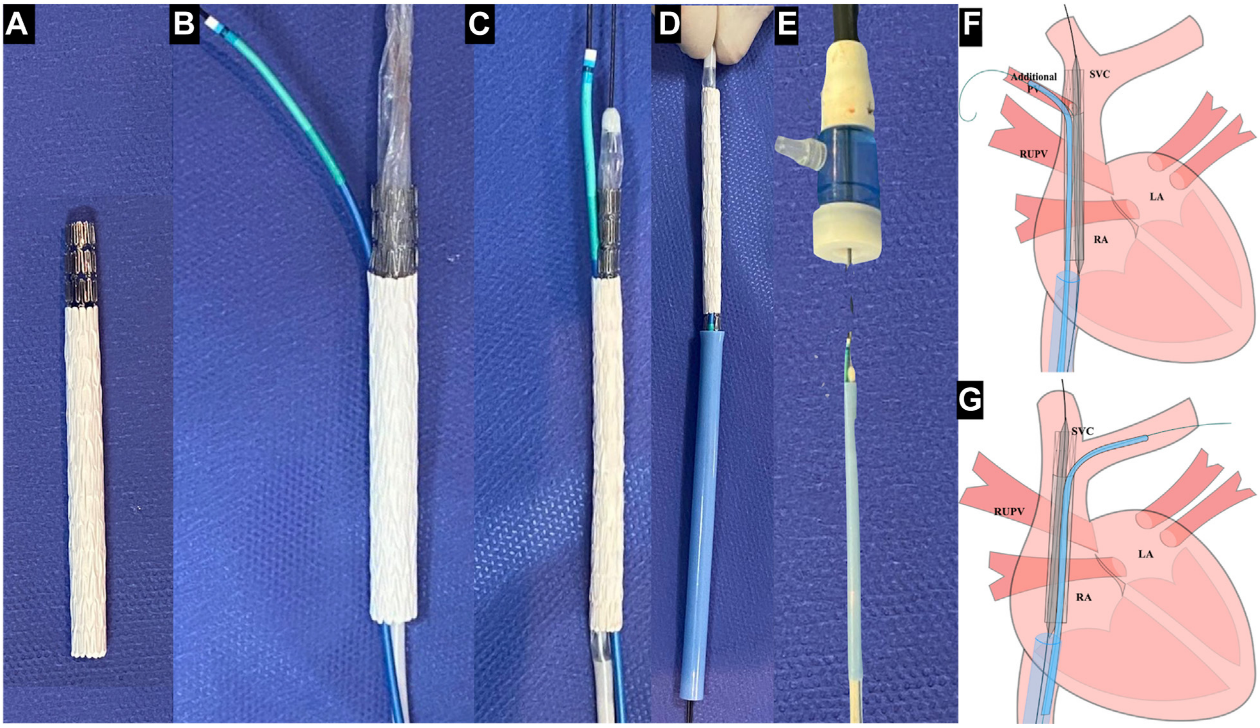

Figure 1.
New hybrid stent and 2-wire deployment technique. Zephyr hybrid covered stent (Sahajanand Laser Technology) is 80.0 mm long and has a cranial 16.0 mm uncovered end (**A**). After minimal predilation of the stent using a short 18-F catheter dilator through its lumen, the stent is mounted on a long balloon with a 5-F coronary guide catheter placed in parallel where the tip of the catheter is brought out of the junction of the covered and uncovered part (**B**). After crimping with a dedicated tool (**C**) and protecting it with a sleeve (**D**), it is advanced into the valve of the long introducer sheath (**E**). The parallel guide wire for the guide catheter is placed either in the additional high-draining pulmonary vein (**F**) or in the left brachiocephalic vein in short superior vena cava (**G**) before advancing the stent balloon assembly through the long sheath. RA, right atrium; LA, left atrium; RUPV, right upper pulmonary vein; SVC, superior vena cava.

echocardiography confirmed complete occlusion of SVD, unobstructed RUPV flow into the LA, and drainage of the additional PV into the SVC through the uncovered portion of stent.

Case 2

A 42-year-old man was diagnosed with SVD with anomalous RUPV drainage to the SVC-RA junction and an additional 6.0-mm vein draining posteriorly into the SVC 12.0 mm cranially to the RUPV. The SVC diameter was 17.0 mm. Balloon interrogation using a 22.0-mm BIB balloon from right femoral venous access and a transseptally placed RUPV pigtail catheter from left femoral vein access confirmed complete closure of the SVD redirecting the RUPV into the LA. A guide catheter cannulated the additional vein from a 24F extra-large Check-flo right femoral venous sheath (Figure 3). Amplatz superstiff and Lunderquist wire were placed from this sheath into the additional vein and right internal jugular vein, respectively. An 80.0-mm Zephyr hybrid stent was mounted on the same BIB balloon along with a coronary guide catheter protruding out from the junction of its uncovered and covered parts. Angiogram confirmed complete SVD closure and redirection of the RUPV to the LA. The additional vein drained into the SVC through the uncovered part. He was asymptomatic on follow-up, while continuing on aspirin and rivaroxaban.

Case 3

Cardiac CT in a 25-year-old woman with SVD showed a short SVC with a diameter of 15.0 mm and length of 10.0 mm from the union of the brachiocephalic veins to the point where the RUPV drained. The hybrid stent design with uncovered portion across the left brachiocephalic vein placement was planned. Two guide wires were advanced from the right femoral extra-large Check-flo introducer, Lunderquist wire in the right jugular vein, and Amplatz superstiff wire in the left brachiocephalic vein. Balloon interrogation performed from right femoral venous access on the Lunderquist wire using a 20.0-mm balloon with RUPV pigtail catheter advanced transseptally from the left femoral vein showed complete closure of SVD (Figure 4). A gradient of 2 mm Hg between the RUPV and the LA and contrast stasis during RUPV angiogram indicated a need for a pulmonary venous protection.[2,3] An 80.0-mm hybrid Zephyr stent was mounted on the same balloon with a parallel coronary guide catheter. The tip of the guide catheter was brought out of the junction of its covered and uncovered part. The upper end of the stent was advanced into the right brachiocephalic vein with the coronary guide catheter diverging into the left brachiocephalic vein before its expansion. Pulmonary vein protection was effected using a 14.0-mm × 4.0-cm Armada 35 balloon (Abbott Vascular) advanced through an 8F Mullins left femoral transseptal sheath and inflated up to 10 atmospheres. A final RUPV angiogram confirmed closure of the SVD and redirection of the RUPV to the LA. There was no pressure difference between the RUPV and the LA after removal of the protective balloon. The side strut of the uncovered part of the long stent facing the left innominate vein was dilated using a 12.0-mm peripheral balloon. Left brachiocephalic vein angiogram confirmed its unobstructed drainage into the SVC. She was asymptomatic on follow-up, receiving dual antiplatelet therapy.

Discussion

Evolving technical modifications in transcatheter closure of SVDs has simplified the procedure and increased the inclusion of almost 94% of patients with SVD despite their anatomical variations.[2] As the wider

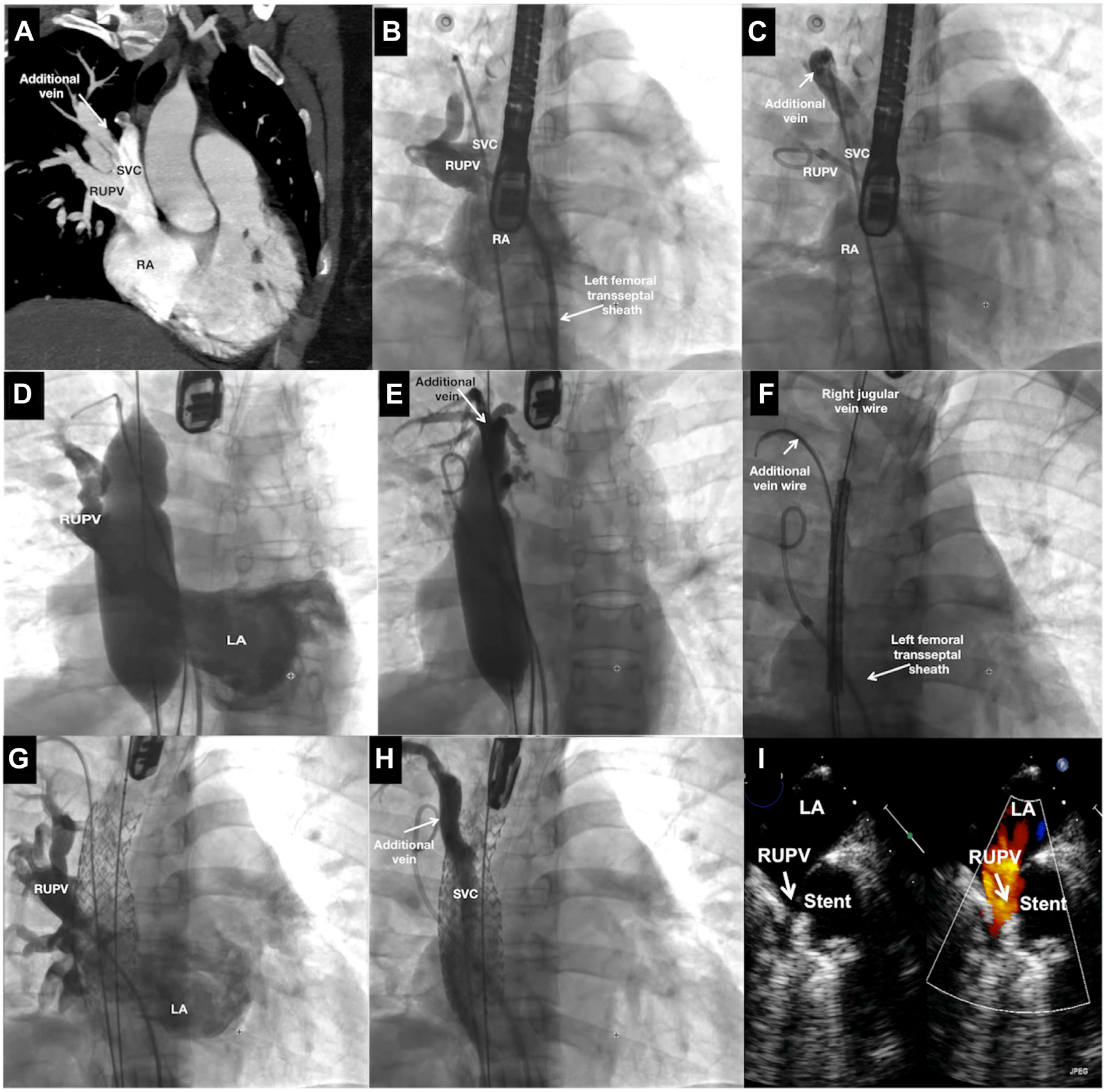

Figure 2.

Sinus venosus defect with additional high-draining pulmonary vein (RUPV). Computed tomography (**A**) shows anomalous RUPV drainage into the superior vena cava (SVC) and a high-draining additional pulmonary vein. RUPV angiogram from a transseptal left femoral venous sheath (**B**), and additional vein angiogram from right femoral vein (**C**) confirms their anomalous drainage into the SVC. Balloon interrogation redirects the RUPV (**D**) to the left atrium (LA) while obstructing the additional vein (**E**). After advancing 2 wires in the right jugular and additional pulmonary veins (**F**), covered stent was deployed, thereby redirecting the RUPV to the LA (**G**). The additional vein continued to drain into the SVC (**H**) without obstruction. Transesophageal echocardiogram on follow-up (**I**) showed absence of residual flows across the defect and RUPV redirected toward the LA.

caudal right atrial end of the stent achieves a bell-bottom configuration, an adequate anchor in the SVC is of paramount importance to stabilize the stent and avoid residual flows from the RUPV into the SVC.[2,6]

Whenever the union of the 2 brachiocephalic veins occurs at a lower level, the short SVC offers a short anchor zone that risks caudal stent migration and embolization. As observed in our third patient, placing the uncovered part in the right brachiocephalic vein allowed drainage of the left brachiocephalic vein through the side struts. The novel twin-wire technique aided by a coronary guide catheter ensured accuracy of the stent placement. The diverging guide wires also prevented caudal migration of the stent until its full expansion anchors the stent to the SVC walls.

When additional high-draining veins are identified in 17% of patients with SVD on cardiac CT, jailing these veins with covered stent may result in localized pulmonary venous infarction and hemoptysis.[3] The novel 2-wire technique after cannulation of the additional vein with a second guide wire ensured correct placement of the uncovered portion of the hybrid stent in the region of the additional veins. The diverging guide wires additionally provided stability as seen in the first 2 patients. A coronary guide catheter with a larger lumen was used rather than a diagnostic catheter in this 2-wire technique to reduce the friction between the catheter and the guide wire.

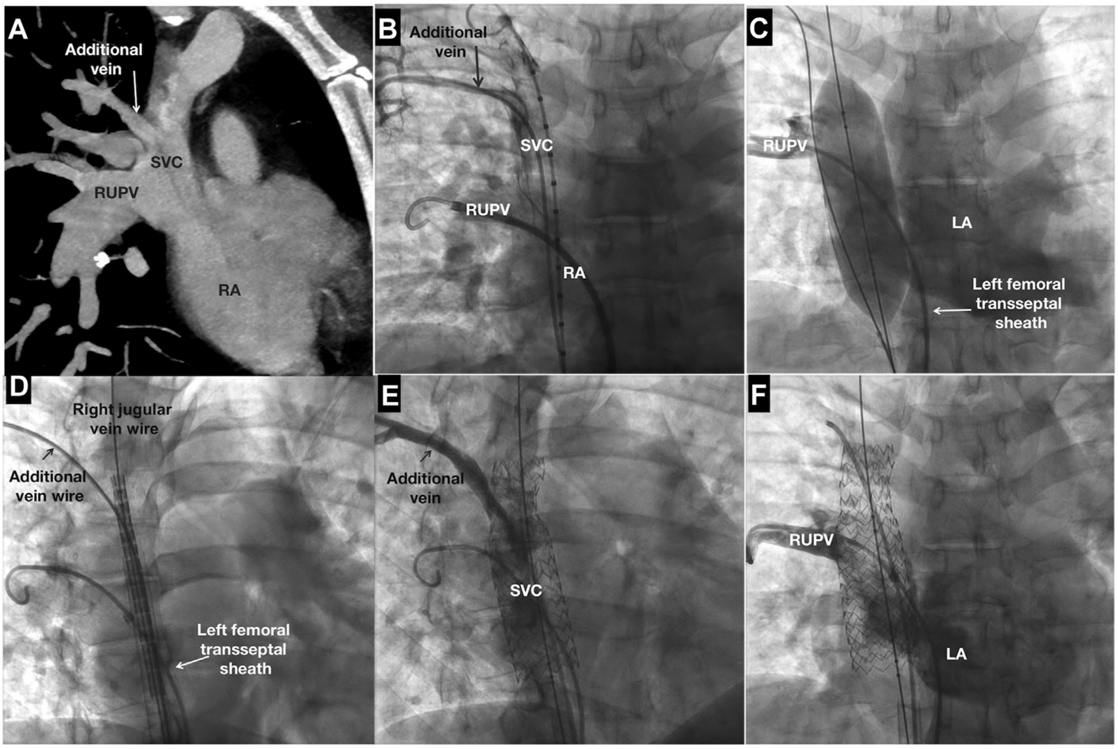

Figure 3.

Sinus venosus defect with additional pulmonary vein. Computed tomography image demonstrates (**A**) anomalous right upper pulmonary vein (RUPV) and additional vein drainage into the superior vena cava (SVC), which are cannulated from left femoral transseptal sheath (**B**) and right femoral sheath, respectively. After balloon interrogation (**C**) confirmed redirection of RUPV to the left atrium (LA), the right jugular vein and additional vein are separately cannulated from right femoral vein sheath for a 2-wire strategy to place the covered stent (**D**). After expansion, the additional vein continues to drain into the SVC (**E**), and the main RUPV is redirected to the LA (**F**).

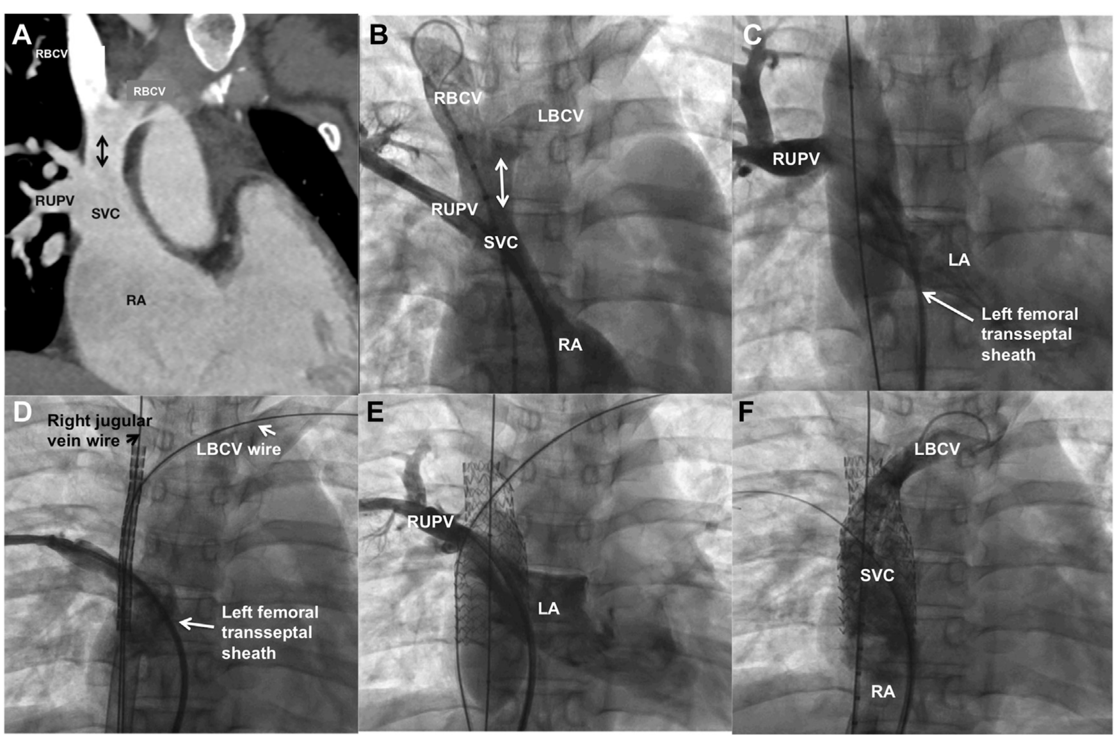

Figure 4.

Short superior vena cava. Computed tomography (**A**) and catheter angiogram (**B**) demonstrate a short anchor zone (arrow) between the union of right brachiocephalic vein (RBCV) and left brachiocephalic vein (LBCV) and the anomalous draining right upper pulmonary vein (RUPV) into the superior vena cava (SVC). RUPV angiogram through left femoral transseptal sheath confirms redirection of the RUPV to left atrium (LA) on balloon interrogation (**C**). After advancing 2 wires into the brachiocephalic veins (**D**), hybrid covered-stent expansion allows redirection of RUPV to LA (**E**) and unobstructed flows from left brachiocephalic vein (**F**).

Conclusions

Transcatheter SVD closure in patients with short SVC anchor zone remains an interventional challenge, with risks of stent embolization or caudal migration leading to residual flows. We report the use of a new hybrid stent design with an uncovered cranial part to overcome these challenges. The novel 2-wire technique with separate cannulation of the right jugular vein and left brachiocephalic vein allowed correction of SVD in patients with very short SVC. Placing the second wire in the additional high-draining pulmonary veins improved stent stability as well as permitted their unobstructed drainage to the SVC. The diverging guide wires provided additional support, which helped to prevent caudal stent migration during deployment in these challenging anatomies.

Declaration of competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship, or publication of this article.

Funding sources

This work was not supported by funding agencies in the public, commercial, or not-for-profit sectors.

Ethics statement and patient consent

This study complied with all ethical standards of the institutional protocols, and informed consent was obtained for the procedure and anonymized reporting.

References

1. Sivakumar K, Qureshi S, Pavithran S, Vaidyanathan S, Rajendran M. Simple diagnostic tools may guide Transcatheter closure of superior sinus venosus defects without advanced imaging techniques. *Circ Cardiovasc Interv*. 2020;13(12):e009833.
2. Sagar P, Sivakumar K, Thejaswi P, Rajendran M. Transcatheter covered stent exclusion of superior sinus venosus defects. *J Am Coll Cardiol*. 2024;83(22):2179–2192.
3. Rosenthal E, Qureshi SA, Jones M, et al. Correction of sinus venosus atrial septal defects with the 10 zig covered Cheatham-platinum stent—an international registry. *Catheter Cardiovasc Interv*. 2021;98(1):128–136.
4. Sivakumar K, Sagar P, Thejaswi P, Ramaswamy R, Chandrasekaran R. Innominate vein occlusion by the fabric of covered stent during transcatheter closure of sinus venosus defects—causes, management, and outcome. *Ann Pediatr Cardiol*. 2024;17(1):59–63.
5. Sagar P, Puthiyedath T, Sivakumar K. First-in-man use of an Indian-made balloon-expandable covered Zephyr stent and intermediate-term follow-up. *Ann Pediatr Cardiol*. 2023;16(1):48–51.
6. Sagar P, Sivakumar K. Different mechanisms for persistent and residual left-to-right shunt after transcatheter sinus venosus defect closure and their management. *Ann Pediatr Cardiol*. 2024;17(1):45–51.